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COUNTRY	USSR	REPORT	[redacted]
SUBJECT	Soviet Documents on Electronic Computers : Digital computers and translating machines	DATE DISTR.	28 February 1957
		NO. PAGES	1
		REQUIREMENT NO.	RD
DATE OF INFO.	[redacted]	REFERENCES	
PLACE & DATE ACQ.			

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SOURCE EVALUATIONS ARE DEFINITIVE. APPRAISAL OF CONTENT IS TENTATIVE.

[redacted] Soviet documents published by the USSR Academy of Sciences, Moscow:

High-Speed Electronic Computer of the Academy of Sciences of the USSR, by S.A.Lebedev, 1955.

The High-Speed Electronic Computer of the USSR Academy of Sciences, BESM, Its Reliability and Methods of Checking, by V.A.Melnikov, 1956.

Les Experiments de la Traduction Automatique de L'Anglais en Russe a L'Aide de la Calculatrice, BESM, by Korolev, S. Rasoumovskiy, and G.Zelenkevich, 1956.

Attachments are not classified when detached from this report.

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trol are carried out in 77 microsecs. Addition and subtraction is carried out in 77 to 182 microsecs., depending on the necessity of equalizing characteristics on normalizing results. Multiplication takes 270 microsecs. and division 288 microsecs. When solving complex problems on the machine, the average operation speed is from 7,000 to 8,000 three-address operations per second, including reference to the magnetic drum and the magnetic tapes. The machine operates 24 hours per day, part of the time being spent on checking. The useful operating time of the machine is 72 per cent, the time spent on checking is 20 per cent, and error losses total 8 per cent (these losses including not only the time required to find the source of trouble in the machine, but that required to repeat the calculations as well).

The machine is checked by means of test programmes with the electron tubes working under worsened conditions (marginal checking). At first special circuits were provided in the machine for marginal checking. Afterwards conditions for marginal checking were secured by changing the incandescence of the tubes. For marginal checking of the memory the displacement in the automatic amplification control units is altered.

The machine is made up of small standard plug-in units. A general view of the machine is shown in the photographs.

ACADEMY OF SCIENCES OF THE USSR
INSTITUTE OF EXACT MECHANICS AND COMPUTING TECHNIQUE

S. A. LEBEDEV

HIGH-SPEED ELECTRONIC COMPUTER OF THE ACADEMY OF SCIENCES OF THE USSR

PUBLISHING HOUSE OF USSR ACADEMY OF SCIENCES
MOSCOW 1955

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THE PAPER
FOR THE INTERNATIONAL CONFERENCE
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IN DARMSHTADT
OCTOBER 1955

PUBLISHING HOUSE OF USSR ACADEMY OF SCIENCES
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The USSR Academy of Sciences high-speed computer (BESM) is a digital electronic machine for the solution of laborious problems in physics, mechanics, astronomy, engineering, etc. In designing the machine emphasis was laid on convenience of programming and simplicity of operation.

A binary system with a floating decimal point was selected. Although the floating decimal point somewhat complicates the logic diagram of the machine, it greatly simplifies programming and mathematical operation. Calculations are made, as a rule, with normalized numbers. If the result of any arithmetical operation, say, subtraction, is unnormal, it is automatically normalized. Besides, provision is made in the machine for carrying out calculations with unnormalized numbers and with result normalization interlocking. The mantissa of the number is represented by 32 binary positions; then, there is one position for the sign of the number, 5 positions for the characteristic of the number and one position for the sign of the characteristic.

Thus, the machine can represent numbers from 2^{-31} to 2^{+31}. The number of digits selected ensures the accuracy required for most problems. In some cases, for instance, when solving certain astronomical problems, the calculations may be carried out on the machine with double the number of digits. Conversion from the decimal

to the binary system and vice versa is effected directly on the machine by means of suitable subprogrammes.

The machine has a three-address system. The code of each address consists of 11 bits, the operation part — of 5 bits; the sixth operation position is for result normalization interlocking. Thus, provision has been made in the machine for 31 instructions. Besides the four arithmetical operations, the results of which are rounded to reduce accumulating errors, there are instructions for multiplication with presentation of the product in double the number of bits and for division with presentation of the remainder for the sake of simplifying calculations employing double the number of positions; several instructions facilitating operations on the characteristics of numbers; instructions for exchange of codes between the separate memory units; conditional and unconditional transfer instructions; a number of logical instructions.

The instructions are selected from the memory by two independent instruction control systems. The set of instructions includes control transfer operations from one system to the other both with and without changing the number to the instruction. Double instruction control facilitates programming transitions to subprogrammes and returns to the main programme.

All operations are carried out by a single universal parallel action arithmetical unit based on trigger cells. The arithmetical unit consists of two receiving registers and an adder. A special circuit has been employed in the adder to eliminate cascade carry. Code addition is effected in less than 3 microsecs. In takes less than 2 microsecs for the codes to shift to the next position. When adding or substracting numbers with different characteristics, the latter are equalized by shifting the smaller number, prior to the actual addition of the codes.

If an unnormal result is obtained, it is normalized by shifting the code to the left and respectively changing its characteristic. Multiplication and division are carried out by addition or subtraction of the code in the adder and shifting.

Special cathode-ray tubes are employed for the memory. There is one tube for every binary position. The capacity of the memory is 1023 numbers. Number selection from the memory and result recording are carried out parallelly. The level of the reading signal at the entrance to the amplifier is 10 mV. A bridge circuit is employed to reduce overloading of the reading amplifier. This has made it possible to reduce the false signal at the entrance to the amplifier when recording, to the level of the reading signal. Moreover, the balance does not depend on the working conditions of the tubes and the supply voltages. The level of the reading signal is adjusted automatically by referring to the control point outside the raster, in which reading and recording are done after every 32 regenerations.

Recording (including preliminary reading) takes 6.5 microsecs., and reading and regeneration—5 microsecs. The full time of reference to the cathode-ray tubes, including the adjustment of the ray and reading, or recording, is 12 microsecs. The memory is provided with automatic internal control, permitting simultaneous verification of all the positions and emission of the corresponding signals.

Besides the cathode-ray tube memory there is a set-up unit based on germanium diodes, having a total capacity of 376 numbers. The desired numbers or instructions can be selected from a memory of this type, but results cannot be recorded in it. The numbers of instructions are set up by punching codes on punchcards. The punchcards are

placed in special arrangements called "books". When the "books" are closed contacts separated from the other circuits by the diode make through the punched holes. Besides the punchcards there is provision for setting up the numbers on a plugboard. The corresponding positions in the "books" and on the plugboard are in parallel. The diode set-up device has also a number of removable units with typical subprogrammes (subprogrammes of trigonometric functions, logarithms, exponent functions, transition from one numerical system to another, etc.) permanently set up (by soldering) in the form of diode matrices. The diode set-up device is employed mainly for typical subprogrammes, for setting coefficients which change from one type of calculation to another, for predetermining the error of coincidence of iterative processes, for manual control of calculations, etc.

In order to extend the sphere of solvable problems to include such as require large storage capacities, the machine is provided with magnetic drum and a magnetic tape storage device.

The magnetic drum had a capacity of 5120 numbers (five groups of 1023 numbers each). Any group of a predetermined number of codes can be transferred to the memory, and vice versa, groups of numbers from the memory can be recorded on the drum. In order to reduce the amount of equipment, a series system of reading and recording on the magnetic drum has been provided. Conversion of the series to the parallel system and vice versa, necessary in exchanging codes between the magnetic drum and the memory, is effected in the arithmetical unit.

There are 84 reading and recording heads mounted on the magnetic drum, 80 of which are for codes, one for clock pulses, one for registering the start pulse and 2

spares. The clearance between the magnetic drum and the heads is of the order of 35 microns. Each track of the drum holds 64 numbers. The recording density is about 3 pulses per millimeter. The drum does 750 revolutions per minute. Hence. the average time spent in waiting for the required code to come under the magnet head is 40 microsecs., the subsequent selection or recording taking place at a rate of 800 numbers per second. The pulse frequency of the magnetic drum amounts to about 35 kilocycles. The amplitude of a reading pulse at the magnetic head constitutes from 50 to 60 mV. Reading and recording amplifiers are provided for each group (5 altogether). They are switched from track to track within each group automatically by means of a special tube-diode circuit.

The magnetic tape storage consists of 4 series action magnetophones with tape 6.5 mm wide. The tape has two tracks. One of them is for recording clock pulses, and the other for code recording. The group number is also recorded on the code track. Like the magnetic drum, the magnetic tapes are for exchanging codes with the memory. The series codes are transformed to parallel ones in the arithmetical unit.

The magnetic tapes can move both forwards and backwards. Only the forward movement is the working stroke. It is during this stroke that any subsequent recorded block is read out, according to a pre-determined number, or that recording is done. The reverse movement is for automatically conveying any block that has passed to the magnetic head. This makes it possible to use the magnetic tape operatively for reading and recording within the limits of one or several integral blocks.

The length of the magnetic tape on each magnetophone is 200 meters. Eight pulses can be recorded on each

millimeter. One tape can hold an order of 30,000 numbers (with allowance for the intervals between groups), making a total of about 120,000 numbers for the 4 magnetophones. The tape reels can be replaced in a very short time, and this is usually done without stopping the machine. The heads are mounted on the magnetophones with high enough precision to permit transposing recorded tape reels from one magnetophone to another. The tape speed is 2 meters per sec. The pulse frequency is 16 kilocycles, and the rate of selection or recording is 400 numbers per second. The amplitude of a reading pulse at the magnetic head is 15 to 20 mV. Each magnetophone is provided with reading and recording amplifiers.

The numbers and instructions are put into the machine from a punched tape in the form of a series code. The punched tape has two tracks, one for clock pulses, and the other for code pulses. The series code is tranformed into a parallel one in the arithmetical unit. The punched codes are read-out by means of photoelectric cells. The reading rate is 20 numbers per second.

The punched tapes are prepared independently on special punchers. For verification purposes two identical tapes are punched independently on different punchers. The punched tapes produced are then compared automatically on a special verifier.

When the data to be put in are the results of calculations carried out on the machine they are recorded on a magnetic tape, and are put in from this tape. In case of an interruption in the calculation of a large problem the used programmes or necessary data are likewise recorded on a magnetic tape. The subsequent input is also from this magnetic tape.

The results of the calculations are withdrawn from the machine by recording on magnetic tape and then printed on a motion picture film independently on a special printing device. The series code passes from the magnetic tape to a shift register, on which it is transformed into a parallel code. Suitable decorders for each digit control pinpoint light sources, which project the image of the digit on a motion picture film. The printing device works at a rate of 200 numbers per second. The film is developed in a developing machine. Paper copies are likewise made in a special machine.

Besides the photographic printing unit, there is an electromechanical printing unit, controlled directly by the machine. The printing rate is 1.5 numbers per second. This printing unit is used when the material to be withdrawn is small in volume compared to the calculations, and to print control values for checking the progress of the calculations.

The controls of the machine are centralized for most operations that fit into the time of the common cycle. A number of elementary operations which are individual for certain instructions and which would substantially slow down the fulfilment of the other instructions if centrally controlled, are carried out by local controls. In carrying out the individual instructions the transition from the central to the local controls and vice versa takes place automatically at the correct moments. The elementary operations under local control include: multiplication, division and number shifts, as well as equalization of the characteristics of numbers and result normalization for addition and subtraction instructions.

The standard cycle of the machine includes selection of two numbers from the memory carrying out the predetermined operation with these numbers, sending the result to the memory and selection of a new instruction from the memory. Instructions not requiring local con-

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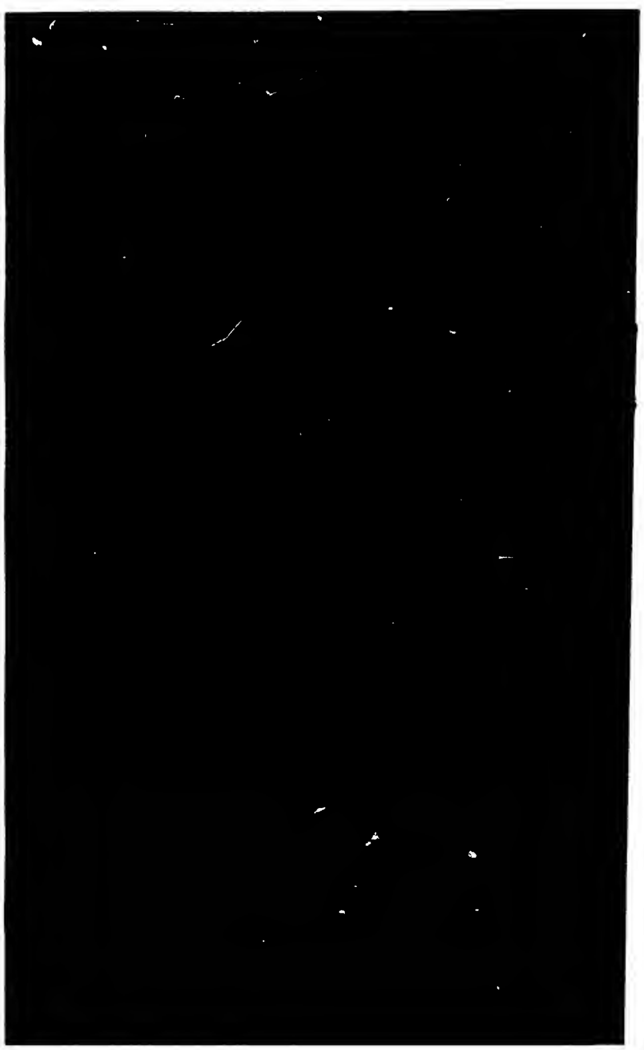
ACADEMY OF SCIENCES OF THE USSR

V. A. Melnikov

THE HIGH-SPEED ELECTRONIC COMPUTER OF THE USSR ACADEMY OF SCIENCES B E S M, ITS RELIABILITY AND METHODS OF CHECKING

MOSCOW, 195[illegible]



ACADEMY OF SCIENCES OF THE USSR

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THE HIGH-SPEED ELECTRONIC COMPUTER OF THE USSR ACADEMY OF SCIENCES B E S M, ITS RELIABILITY AND METHODS OF CHECKING

MOSCOW, 1956

The high-speed electronic computer of the USSR Academy of Sciences (BESM) was developed at the Institute of Precise Mechanics and Computing Technique by Academician S. A. Lebedev and his associates.

The BESM is a digital electronic machine for the solution of laborious problems in physics, mechanics, astronomy, engineering, etc. In designing the machine emphasis was laid on convenience of programming and simplicity of operation.

A binary system with a floating decimal point was selected. Calculations are made, as a rule, with normalized numbers. If the result of any arithmetical operation, say, subtraction, is unnormal, it is automatically normalized. Besides, provision is made in the machine for carrying out calculations with unnormalized numbers and with result normalization interlocking. The mantissa of the number is represented by 32 binary positions; then, there is one position for the sign of the number, 5 positions for the characteristic of the number and one position for the sign of the characteristic.

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fected in less than 3 microsecs. In takes less than 2 microsecs for the codes to shift to the next position.

The standard cycle of the machine includes selection of two numbers from the memory carrying out the prede-

Fig. 1. The arithmetical unit.

termined operation with these numbers, sending the result to the memory and selection of a new instruction from the memory. This cycle takes 77 microsecs.

Addition and subtraction carried out in 77 to 182 microsecs., depending on the necessity of equalizing characteristics on normalizing results. Multiplication takes 270 microsecs. and division 288 microsecs.

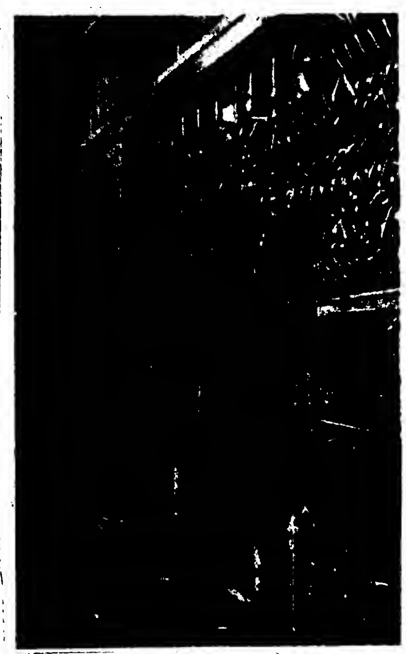

Fig. 2. A general view of the cathode-ray tube memory.

Special cathode-ray tubes are employed for the memory. There is one tube for every binary position. The capacity of the memory is 1023 numbers. See fig. 2.

Number selection from the memory and result recording are carried out parallelly.

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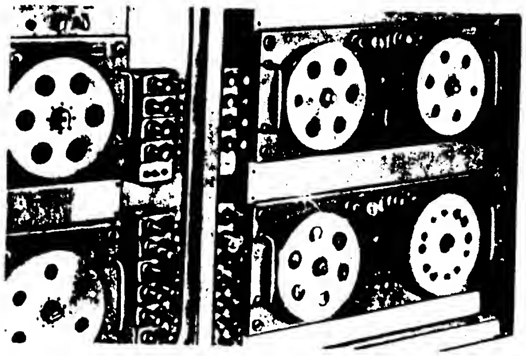

Fig. 3. The magnetic tape storage device.

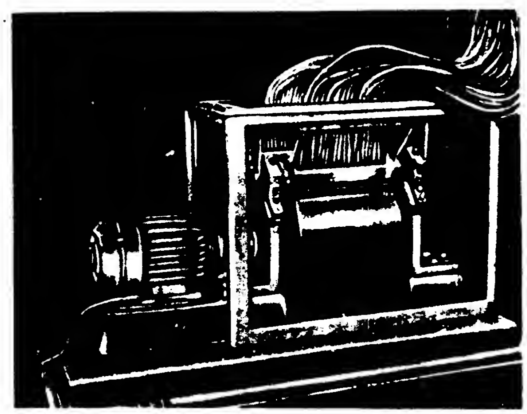

Fig. 4. The magnetic drum.

The magnetic drum had a capacity of 5120 numbers (five groups of 1023 numbers each). Any group of a predetermined number of codes can be transferred to the memory, and vice versa, groups of numbers from the memory can be recorded on the drum. In order to reducc the amount of equipment, a series system of reading and recording on the magnetic drum has been provided. Conversion of the series to the parallel system and vice versa. necessary in exchanging codes between the magnetic drum and the memory, is effected in the arithmetical unit.

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The numbers and instructions are put into the machine from a punched tape in the form of a series code. The punched tape has two tracks, one for clock pulses, and the other for code pulses. See fig. 5 and 6.

The punched codes are read-out by means of photoelectric cells. The reading rate is 20 numbers per second.

The punched tapes are prepared independently on special punchers.

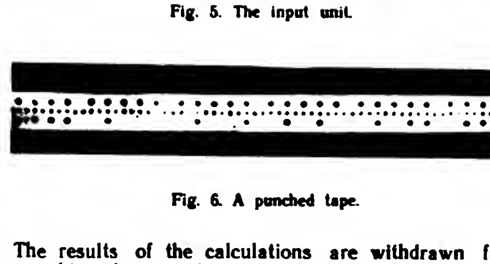


Fig. 5. The input unit.

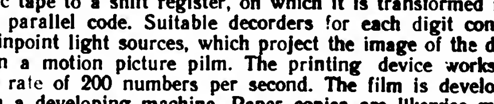


Fig. 6. A punched tape.

The results of the calculations are withdrawn from the machine by recording on magnetic tape and then printed on a motion picture film independently on a special printing device. The series code passes from the magnetic tape to a shift register, on which it is transformed into a parallel code. Suitable decorders for each digit control pinpoint light sources, which project the image of the digit on a motion picture pilm. The printing device works at a rate of 200 numbers per second. The film is developed in a developing machine. Paper copies are likewise made in a special machine. See fig. 7 and 8.

Besides the photographic printing unit, there is an electromechanical printing unit, controlled directly by the machine. The printing rate is 1.5 numbers per second.

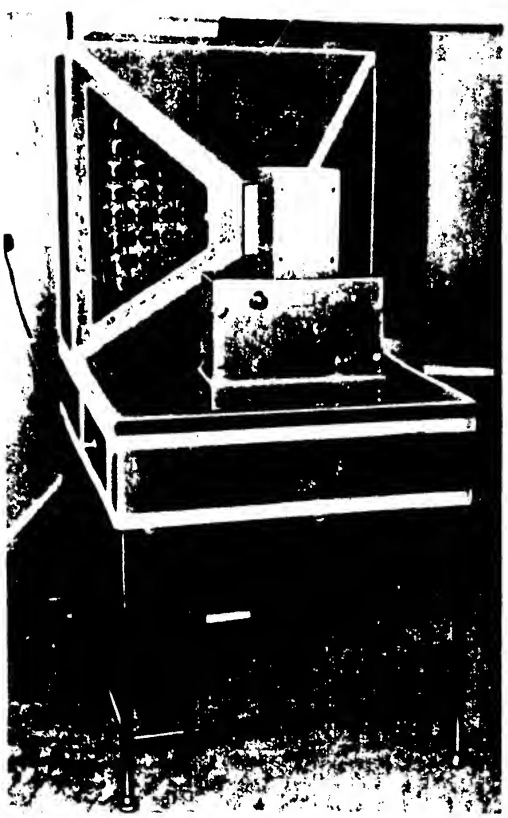


Fig. 7. The photoprinter.

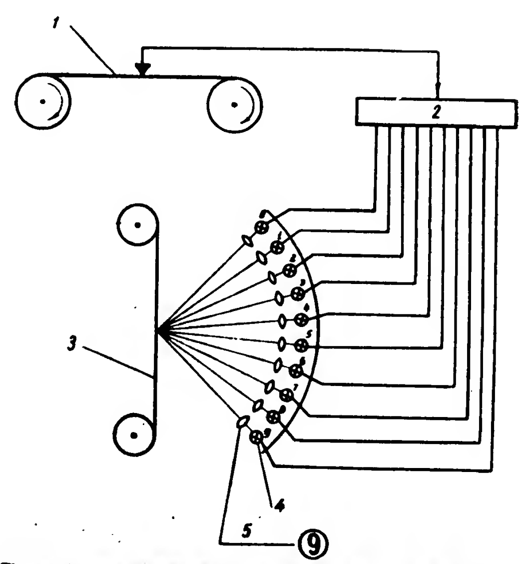


Fig. 8. A general diagram of the photoprinter. 1. — magnetic tape; 2. — decoder; 3. — film; 4. — neon lamp; 5. — lens.

This printing unit is used when the material to be withdrawn is small in volume compared to the calculations, and to print control values for checking the progress of the calculations. See fig. 9.

Electronic computers are characterized by their stability and reliability in operation as well as by their storage capacity and access times. It is general practice to have the machine inspected regulary in order to keep it operating properly.

Reliability of the machine is guaranteed if special checking procedure has been carried out, in the course of which every element of the machine was given marginal-checking and those of them that proved unreliable were replaced by reliable ones.

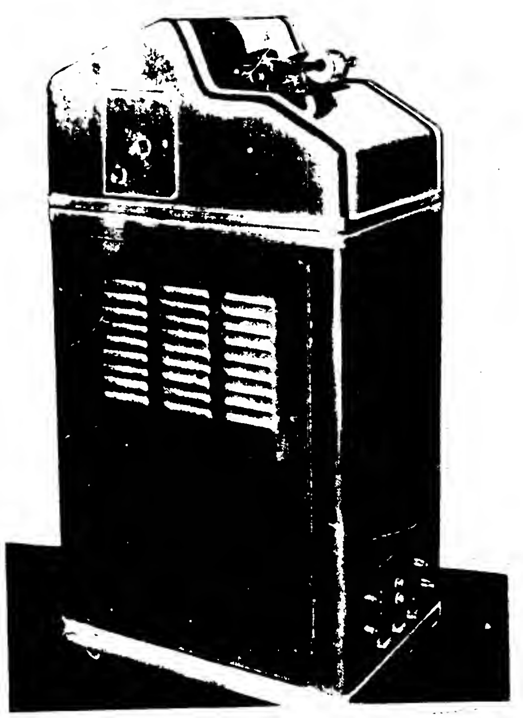


Fig. 9. A general view of the electromechanical printing unit.

The BESM machine of the USSR Academy of Sciences has been in operation since 1952. During this period special methods of checking procedure have been worked out with special test programmes which make it possible quickly to eliminate trouble in the machine which may lead to errors in doing problems.

The BESM is basically made up of separate strandard plug-in-units assembled on two-tube or four-tube chassis These units are mounted on racks between which the inter-unit connections are made. The control unit and the arithmetical unit take up a separate rack. Both operative memory and the external magnetic drum and magnetic tape storage devices are also mounted on separate racks. This individual location of the separate units greatly facilitates technical maintenance by making it possible to carry out prophylactic preparations and to check the machine rack by rack, independently of one another.

There are 8 types of standadt plug-in-units;

1. Trigger;
2. Gate;
3. Shaper;
4. Cathode follower;
5. Amplifier with electromagnetic delay line;
6. Inverter;
7. Diode unit;
8. «Ripple through» carry unit.

These are the types of plug-in units the control and arithmetical unit circuits as well as those of the automatic control are made of. Thus it becomes clear that the reliability of the machine depends to a considerable extent on the reliability of the standard plug-in-units.

The most important factors influencing stability of operation are the following:

a) time variation of the parameters of the electronic tubes;

b) appearance of poor contacts in some of the circuits, due to inevitable vibrations of the machine, contamination and oxidation of the contact surfaces;

c) time variation of the resistance parameters. It is obvious, that tubes and circuits of low reliability should be detected beforehand to guarantee the reliability of the machine at work. In designing the BESM methods of checking procedure of the standard plug-in-units were devised, based on alterations in some of the feed voltages. Tumbler switches were provided so that different groups of units could be tried under marginal conditions. However, experience in operation showed that the methods provided for the marginal checking did not prove sufficiently effective (with very few exceptions).

While running the machine we have learnt, that the best method of checking the tubes in the BESM for emission loss is that of decreasing the incandescence.

This method proved efficient for all the types of standard plug-in- units. The only exception is the trigger. In the case of the trigger, besides lowering the incandescence, another method should be used, which includes changing the divider bias 3 to 4 per cent, thus disturbing the symmetry of the trigger. By using this method both the tube and the stability of the divider resistances are checked, the latter being of great influence on the stability of operation of the trigger.

The possibility of checking the units by lowering the incandescence is due to the fact that the cathode current of a tube which has lost its emission depends greatly on the incandescence, while that of a new tube remains practically constant with incandescence fluctuations within ± 10 per cent.This property is utilized in the checking procedure, of the standard plug-in-units. The presence of false signals is revealed by the method of increasing the incandescence.

Malfunctions sometimes occur and their frequency and their nature does not change when the incandescence, current frequency of feed voltages are varied. Malfunctions of this kind are usually due to unreliable contacts or the plug-in units being insufficiently shockproof.

This is the reason why regular checking must be carried out once or twice a month for shockproofnees. For this purpose a test programme is put into the machine while panels and separate units are tapped. In most cases either poor contacts are found on the tube panels or poor solder joints in the asembly. Poor contacts in the plugs and sockets by which the unit is connected to its rack practically do not occur.

The same methods of checking procedure are used for the non-standard units in the storage devices. An additional position checking is carried out in the operative cathode-ray tube memory. This is done by checking the rewriting of code «1» into code «0» and vice versa in all the positions of the storage unit with a corresponding bias change on the read-out gates.

The following test programmes were compiled for complete checking of the machine:

1. A programme for checking the main operations.
2. A programme for checking the adder with a variable code.
3. A programme for checking the special plug-in-units.
4. A programme for checking the internal and external storage devices.
5. A programme for checking the operative memory for «rewriting».
6. A programme for checking the operative memory for multiple reference.

Test programme checking is similar to the operation duty in doing problems.

All the test programmes are recorded in one of the groups of the magnetic drum, and are kept there all the time. When checking is necessary, reading out the programmes takes only a few seconds. The time needed for a single fulfilment of al the test programmes is 1 minute

Any of the test programmes can be easily extracted by manipulations at the central control desk, in case rapid checking of the machine is required. Tumbler switches on the control desk can be used to set up automatic successive fulfilment of the test programmes or cyclic fulfilment of one of them. If all the test programmes are fulfilled satisfactorily under the marginal conditions, the machine may be considered ready for computations.

The statistics collected shows that the work carried out with a view to improving certain units of the machine as well as continuous improvement of the checking procedure methods, have made it possible to improve considerably the stability and reliability of operation of the machine.

When solving complex problems on the machine, the average operation speed is from 7,000 to 8,000 three-address operations per second, including reference to the magnetic drum and the magnetic tapes. The machine operates 24 hours per day, part of the time being spent on checking. The useful operating time of the machine is 72 per cent, the time spent on checking is 20 per cent, and error losses total 8 per cent (these losses including not only the time required to find source of trouble in the machine, but that required to repeat the calculations as well). See fig. 10.

The time of operation without malfunctions for periods of ten consecutive hours and more constitutes about 70 per

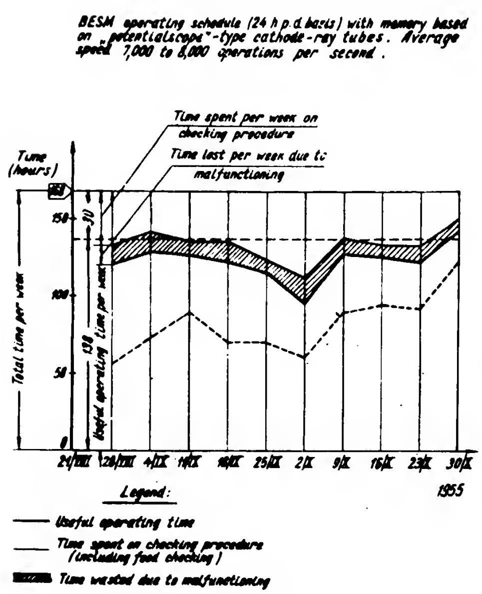
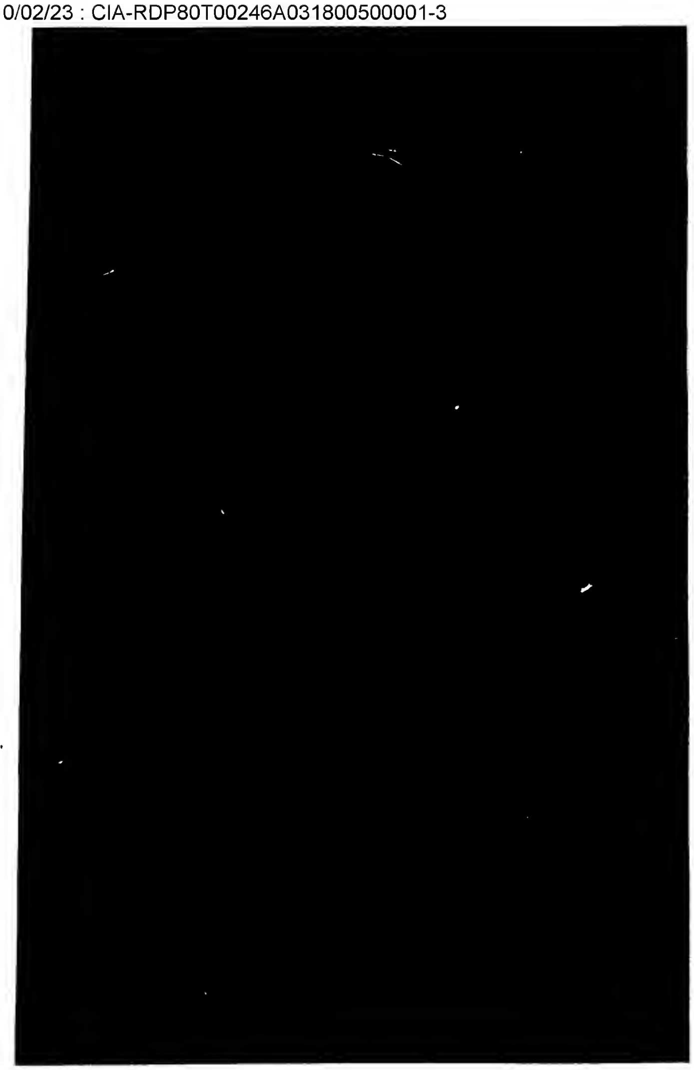


Fig. 10. The BESM operating shedule (24 h. p. d.).

cent of the useful operating time. The maximum time of operation registered without a single malfunction was 42 hours. Table 1 shows the percentage of mulfunctions traced to various units.

TABLE 1

Arithmeti-cal unit and control unit	Internal storage unit	Magnetic storage unit	Diode set-up unit	Electro-mechanical printing unit	Feed unit	Cause of malfunction not estab-lished
13 p. c.	32 p. c.	20 p. c.	4 p. c.	9 p. c.	10 p. c.	12 p. c.



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ACADEMIE DES SCIENCES DE L'URSS

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Le travail de la traduction automatique de l'anglais en russe a été commencé par l'Institut de Mécanique Exacte et de Technique de Calcul et par l'Institut d'Information Scientifique de l'Académie des Sciences de l'U.R.S.S. Les collaborateurs scientifiques suivants ont pris part à ce travail: D. Yu. Panov, I. S. Mouchin, I. K. Belskaia, S. N. Rasoumovski, L. N. Korolev, G. P. Zélenkevitch.

Les expériments de la traduction ont été réalisés par la calculatrice électronique Б.Э.С.М. Cette machine a été construite par l'académicien Lébédev.

Les plus importants progrès de la technique de la dernière dizaine d'années se sont manifestés dans la construction des calculatrices électroniques sous le contrôle de programme.

Les calculatrices universelles électroniques modernes effectuent plusieurs milliers d'opérations arithmétiques dans une seconde et elles remplacent le travail de plusieurs dizaines de milliers d'hommes-calculateurs.

Il est patent que la grande vitesse avec laquelle les opérations arithmétiques s'effectuent, n'aurait aucun sens si l'on ne pouvait pas complètement automatiser le procès de calcul qui contient l'ordre établi d'exécution des opérations et qui conserve les résultats intermédiaires pour leur utilisation soivante etc.

Il faut marquer à part les commandes du passage conditionnel qui permettent à la machine, selon les résultats de calcul, de passer automatiquement de remplir l'une ou l'autre séquence des commandes, c'est-à-dire de choisir la voie des calculs suivants. On peut donc questionner la machine; elle répondra selon les circonstances «oui», ou «non».

On appelle les commandes du passage conditionnel «les points de la bifurcation de programme». Les programmes affectés à effectuer les problémes logiques ont beaucoup de points de la bifurcation, tandis que les programmes des opérations de calcul ont peu de points pareils.

Le nombre de points de la bifurcation détermine la complexité de la structure de programme quand on le compose.

La possibilité de modifier les commandes du programme, au cours du travail, et de choisir la voie suivante de calculs selon les résultats obtenus, permet d'utiliser les calculatrices électroniques pour exécuter une vaste classe d'opérations logiques.

L'opération de la traduction automatique d'une langue en autre se réfère à la même catégorie d'opérations.

Depuis le janvier 1955, le groupe des collaborateurs scientifiques de l'Institut de Mécanique Exacte et de Technique de Calcul et les collaborateurs scientifiques de l'Institut d'Information Scientifique de l'Académie des Sciences de l'URSS commença à développer les problèmes de la traduction automatique de l'anglais en russe.

Au bout de 1955 on a reçu les premières traductions expérimentales effectuées par la calculatrice électronique БЭСМ (la construction de l'académicien Lébédev).

Ces résultats expérimentaux ont montré qu'il est possible de créer le système de l'analyse de proposition qui permet de fixer le sens de tous les mots de cette proposition en se basant sur les connaissances de la grammaire et du lexique de la langue. Le système pareil ne dépend pas pratiquement du vocabulaire et convient à la traduction non seulement du texte spécialement choisi mais il convient à tous les textes aux éléments techniques et scientifiques du profil choisi.

Il est vrai que la langue est le moyen des rélations entre les gens et qu'elle représente le système déterminé dont le sens des mots et de leurs modifications peut être exprimé par les moyens lexicaux et grammaticaux. Ces moyens s'énoncent comme les règles définies du lexique et de la grammaire, comme les lois de la construction de la phrase. En conséquence, it est possible d'élaborer les règles de la traduction qui prendront en considération toutes les particularités de la langue et permettront d'établir le sens des mots et les rapports entre les mots dans la proposition. En d'autres termes, il est possible d'établir les règles de la traduction automatique qui permettront d'effectuer, à condition de leur satisfaction, la traduction sans travailler préalablement et sans réviser ensuite des phrases et des textes différents.

Il est nécessaire d'avoir le dictionnaire pendant la traduction ordinaire et pendant la traduction à l'aide de la machine.

La calculatrice électronique opère sur les nombres, c'est pourquoi les mots dans le dictionnaire doivent être représentés sous une forme de nombres, c'est-à-dire ils doivent être codés. En mettant, par exemple, les nombres du code connu Bodo (fig. I) en conformité avec chaque lettre de l'alphabet latin et de l'alphabet russe, nous aurons la possibilité d'inscrire chaque mot anglais et sa traduction russe par le nombre définitif, qui est l'unique pour ce mot.

a — 16	f — 14	k — 19	p — 24	u — 20
b — 06	g — 10	l — 27	q — 23	v — 29
c — 22	h — 26	m — 11	r — 07	w — 13
d — 30	i — 12	n — 15	s — 05	x — 09
e — 08	j — 18	o — 28	t — 21	y — 04
				z — 25

Fig. 1. Le codage de l'alphabet latin.

Par exemple, les mots:

There, short, into, numerical, methods

on inscrira sous l'aspect de nombres.

2126080708, 0526280721, 12152128, 15201116071222l627, 11082126283005.

Chaque mot a son code et son numéro d'ordre (de vocabulaire) définitif.

Le vocabulaire affecté à la traduction automatique se distingue du vocabulaire ordinaire, car il a une série de renseignements supplémentaires (des indices) qui se rapportent à la grammaire du mot russe, sauf le mot russe qui correspond au mot anglais donné. Pour le nom ce sont des renseignements suivants: genre, déclinaison, thème mouillé ou dur présence ou absence du chuintant dans le thème, quel objet signifie le mot: animé ou non etc.

Pour le verbe ce sont: conjugaison, aspect etc.

Pour l'adjectif — thème mouillé ou dur, degrès de comparaison etc.

On code les principes de grammaire selon les règles établies. Ces principes occupent 39 digits binaires, se représentant une cellule de mémoire. Les codes des mots anglais et les codes de leurs indices se représentent la partie «anglaise» du vocabulaire.

La seconde partie du vocabulaire est «russe», elle comporte des mots russes inscrits selon l'ordre de leurs numéros indiqués dans la partie anglaise du vocabulaire.

On avait préparé le vocabulaire composé de 952 mots anglais et de 1073 mots russes pour les expériments, réalisés dans la machine БЭСМ. Si l'orthographe du mot du texte correspond exactement à l'orthographe du mot du vocabulaire c'-est-à-dire si les deux mots sont représentés par les mêmes nombres, on peut le constater facilement à l'aide de l'opération de comparaison. Le choix des mots dans le vocabulaire est basé sur ce principe.

Pour choisir les mots qui prendront quelques terminaisons (en anglais ce sont -s, -ing, -ed, -er, -est, -e, -y, etc), il faut supprimer ces terminaisons et recommencer les recherches du mot sans la terminaison dans le vocabulaire.

C'est trés facile de trouver les mots monosémantiques dans le vocabulaire. Mais c'est plus difficile de déterminer le sens du mot dont on a besoin si le mot est polysémantique. Pour déterminer le sens du mot polysémantique qui convient à la phrase donnée il faut faire l'analyse des mots voisins, examiner leurs significations et leurs caractéristiques grammaticales. Les règles pour déterminer la signification nécessaire du mot polysémantique sont basées sur l'analyse du grand matériel et elles sont composées en schéma qu'on appelle «supplément».

Cette schéma contient de même les expressions idiomatiques. On peut ordinairement mettre en relief «le mot typique» dans chaque expression de ce genre, le mot qui se rencontre dans toutes les variantes de cette expression idiomatique.

On a donné à ce mot l'indice «polysémantique» dans le vocabulaire. Le supplément comprend le contrôle des mots voisins pour constater que le mot ne fait pas partie de l'expression idiomatique.

Si la réponse est positive, toute l'espression idiomatique se traduit de l'expression équivalente. Par exemple, le mot anglais «able» on traduit ordinairement comme l'adjectif «способный», mais en combinaison avec les formes verbales «be» (is, are, were, been, being), c'est mieux de le traduire comme le verbe «мочь».

En conséquence, avant de traduire le mot «able» en russe comme «способный», il faut examiner le mot précédent «be, are», etc. en cas de la réponse positive il faut traduire toute la locution comme «мочь».

Il faut noter que les plus simples et les plus généraux critères du choix de la signification d'un mot ou d'une expression sont les résultats du travail préliminaire du matériel analysé par les linguistes. La traduction dépend beaucoup de cas typiques qui doivent être tous prévus et pris en considération dans le programme.

Si un des mots de la phrase manque dans le vocabulaire, la mémoire conserve ce mot sans le modifier. Quand la phrase traduite sort de la machine, le mot dont on n'a pas trouvé la traduction est imprimé en lettres latines.

Le texte anglais s'introduit à la machine phrase par phrase. D'abord on enregistre ce texte sur le ruban de papier par l'intermédiaire du perforateur de lettre en conformité du code adopté Bodo.

La phrase s'introduit ensuite du ruban perforé à la mémoire intérieure de la machine.

Par exemple, la phrase codée: «There are two various numerical methods» passe dans la mémoire intérieure comme un nombre qui a soixante dix huit chiffres:

21260807080016070800211328002916071228200500152011080712221627001108212628300 5

Puis on partage la phrase en mots et commence à chercher ces mots dans le vocabulaire.

La vitesse de la traduction dépend beaucoup de recherches des mots dans le vocabulaire.

En conséquent, on doit prêter grande attention aux questions d'accélération du travail de cette partie de programme.

Voilà une de ces méthodes de recherches des mots: Les codes des mots anglais sont disposés dans le vocabulaire par l'ordre d'accroissement des nombres dont ils représentent.

En choisissant n'importe quel mot dans le vocabulaire et en comparant son code avec le code du mot cherché nous pouvons répondre à la question: où nous devons chercher le mot nécessaire dans le vocabulaire (plus haut ou plus bas). Ce procès ressemble à la méthode employée pour trouver les racines des équations selon la méthode de «position fausse».

Pour trouver n'importe quel mot dans le vocabulaire comportant 10 000 mots, suivant cette méthode, on aura besoin de 14 vérifications pareilles ($14 \approx \log_2 10\,000$), et pour trouver le mot dans le vocabulaire comportant 30 000 mots on n'aura besoin plus que 15.

Quand le mot est trouvé dans le vocabulaire, on choisit du vocabulaire toutes les informations à propos de ce mot: le numéro de ce mot dans la partie anglaise du vocabulaire, le numéro du mot russe correspondant au mot anglais, les informations grammaticales se rapportant à ce mot russe. Cette information est une équivalent numérique du mot.

Toutes les opérations suivantes se réalisent avec ces équivalents numériques. On laisse deux cellules de mémoire pour coserver un équivalent numérique, les nombres qui désignent les parties du discours et leurs caractéristiques grammaticales on met dans la même place de cellule.

Cela permet de distinguer et de choisir automatiquement les indices nécessaires.

Les équivalents ne sont pas seulement des garages d'informations des mots. Le remplacement des mots par leurs équivalents assure l'universalité des schèmes grammaticaux et des programmes qui les réalisent. Finalement, les schèmes et les programmes deviennent indépendants de la phrase concrète et du vocabulaire.

On partage le programme de la traduction automatique en deux parties: l'analyse et la synthèse. (Fig. 2).

Le but de la première partie est de déterminer la forme grammaticale des mots russes nécessaires, leur place dans la proposition traduite, selon l'orthographe des mots anglais, leur place dans la proposition et leurs indices grammaticaux pris du vocabulaire. Les informations obtenues s'expriment par les indices et elles permettent de passer à la seconde partie du programme, c'est-à-dire, à la synthèse de la proposition russe. Les mots russes qui se trouvent dans le vocabulaire, par l'intermédiaire de ce programme, prennent la forme grammaticale correspondante aux indices obtenus par l'analyse.

La grammaire est représentée dans la phrase russe et dans la partie anglaise du vocabulaire comme les schèmes spéciaux sur les principales parties du discours: l'adjectif, l'adjectif numéral etc. L'analyse dichotomique est à la base du travail de chaque schème, c'est-à-dire c'est un système du «contrôle» de la présence ou de l'absence de n'importe quel indice grammatical morphologique ou syntaxique du mot analysé. Il est possible deux réponses sous le contrôle: la réponse positive et la réponse négative. Chacune d'eux permet de donner la conclusion définitive et de recevoir les indices nécessaires au mot en question ou de continuer le contrôle pour montrer la présence de l'indice caractéristique suivant jusqu'à ce que la réponse définitive et l'indication des indices grammaticaux qu'on doit obtenir par le mot donné ne soient pas reçues. Les parties particulières du programme sont disposées par ordre qui assure l'obtention des indices nécessaires à effectuer les actions qui suivent. Comme le but final du schème de l'analyse est d'obtenir des indices correspondants aux mots russes, les schèmes dichotomiques répondent à la question duquel mot on doit prendre ces indices. Par exemple, le nom peut prendre son cas de la préposition ou de l'adjectif numéral qui le précède.

Les schèmes de la synthèse russe ne dépendent pas de la langue dont on traduit. Les indices donnés dans le vocabulaire et recus par les programmes de schèmes

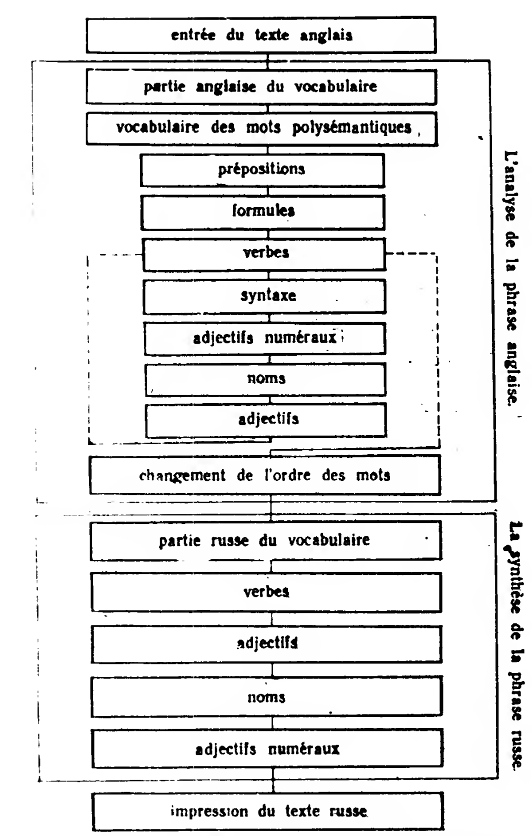

Fig. 2. Le schème du programme de la traduction automatique du russe en anglais.

de l'analyse assurent complétement l'obtention de la forme nécessaire du mot russe. De ce côté les schèmes de la synthèse russe dépendent de la partie russe du vocabulaire. La structure de la construction des schèmes russes dépend du rôle du vocabulaire. On avait admis à conserver les mots dans son essentiel, c'est-à-dire, on doit conserver les adjectifs au masculin, au singulier, au nominatif; les verbes — à l'infinitif etc. Les schèmes russes réalisent, pour la plupart, dans ce cas, le changement de terminaisons des mots pris du vocabulaire et ils tiennent compte de l'alternance de voyelles et de consonnes quand on en a besoin.

Les schèmes russes de la synthèse opèrent sur le mot et ses indices et on n'a pas besoin de prêter attention aux mots voisins. C'est la distinction principale des schèmes russes de la synthèse et les schèmes de l'analyse (des schèmes anglais dans ce cas).

Examinons les étapes successives de la traduction par la machine. Prenons, par exemple, la phrase anglaise:

«The cause of this phenomenon will be considered in the following articles».

Cette phrase codée s'introduit dans la mémoire intérieure comme un nombre qui a cent quarante six chiffres

21260800221620050800281400212612050024 26
0815281108152815001312272700060800222815 05
12300807083000121500212608001428272728
1312151000160721122222708 05

Puis on la repart en mots et cherche chaque mot dans le vocabulaire.

On ne trouve que cinq mots dans cette phrase dont chacun a une seule signification et les indices russes correspondants:

phenomenon — traduction: явление; le nom, neutre, I déclinaison, thème mouillé, anglais.

consider — traduction: рассматривать; le verbe, I conjugaison, aspect imperfectif, il exige l'accousatif, angl.

article — traduction: статья; le nom, du féminin.

will — on ne le traduit pas, le verbe.

be — traduction: быть; le verbe, I conjugaison, aspect perfectif, anglais.

Il est à noter que la machine a trouvé les mots «consider» et «article» après avoir supprimé la terminaison «s»

du mot «articles» et la terminaison «ed» du mot «con sidered». On l'a marqué dans les équivalents de ces mots.

On marque que les autres mots ont beaucop de significations dans le vocabulaire et on doit faire l'analyse de cette phrase pour choisir les significations nécessaires à ces mots.

Le mot anglais «in» qu'on traduit souvent comme «в» (préposition), on peut traduire dans certaines locutions autrement. Par exemple, dans la locution «interest in . . . интерес к . . .», on le traduit comme «к» (préposition). On peut le traduire comme «с», «при», etc. On voit d'après le contrôle des mots voisins de cette phrase qu'il faut traduire «in» comme «в» (préposition).

Un autre exemple: le mot «follow». On le traduit dans la locution «follow» soit «такой» soit «следующим образом» selon certaines conditions qu'on doit accomplir. Dans les autres cas, on le traduit comme «следовать».

L'information, prise du vocabulaire, obtenue au moyen de l'analyse des mots polysémantiques s'inscrit comme la séquence d'équivalents des mots de la phrase en question. Les numéros russes d'équivalents correspondent à la traduction suivante mot à mot:

причина	этот	явление	быть
рассматривать	и	следовать	статья

Il est évident qu'on ne peut pas traduire certains mots anglais en russe (the, of, will) et on donne une remarque nécessaire à leurs équivalents («vide» dans les classes du numéro russe).

En travaillant les équivalents de mots de cette phrase, les programmes de l'analyse grammaticales complètent les équivalents initiaux par une série des indices nécessaires au travail des programmes de la synthèse russe. Par exemple, les programmes obtiennent pour le mot «article» les indices supplémetaires suivants: pluriel (parce qu'on a supprimé la terminaison «s»), puis prépositionnel (parce qu'on met devant le mot la préposition «в») Ces indices et les indices pris du vocabulaire sont suffisants pour obtenir la terminaison correcte du mot «статья» par l'intermediaire du programme russe.

Le programme du verbe anglais obtient les indices supplémentaires suivants pour le mot «follow»: le participe présent (parce qu'on a omis la terminaison «ing») et les indices du pluriel et du prépositionnel qu'on prend du nom suivant.

A la fin du travail des programmes «anglais» de l'analyse aux équivalents et des programmes «russe» de la synthèse aux mots de sous-texte choisis dans la partie russe du vocabulaire, on recoit la traduction définitive·

Причина этого явления будет рассмотрена в следующих статьях.

Il faut mettre en relief que dès l'entrée de la phrase anglaise dans la machine, la traduction se fait automatiquement sans aucun intervention de l'homme. Les philologues et les mathématiciens ont beaucoup travaille préalablement pour faire traduire la machine de cette façon.

Les expériments de la traduction automatique réalisée à l'U.R.S.S. et à l'etranger laissent espérer que le temps est proche où l'on réalise l'automatisation de la traduction du texte aux éléments scientifiques et techniques sur la plus vaste échelle.

Pour conclure, citons quelques exemples des phrases anglaises et leurs traductions russes, obtenues par la machine **Б.Э.С.М.**

When a practical problem in science or technology permits mathematical formulation, the chances are rather good that it leads to one or more differential equations. This is true certainly of the vast category of problems associated with force and motion, so that whether we want to know the future path of Jupiter in the heavens or the path of an electron in an electron in an eectron microscope we resort to differential equations. The same is true for the study of phenomena in continuous media, propagation of waves, flow of heat, diffusion,

Если практическая задача в науке или технике допускает математическую формулировку, шансы довольно велики что это приводит к одному или более дифференциальным уравнениям. Это верно безусловно для обширной категории задач связанных с силой и движением, так что хотим ли;мы знать будущий путь Юпитера в небесах или путь электрона в электронном микроскопе мы прибегаем к дифференциальным уравнениям. То же верно для изучения явлений в непрерывной среде, распространения волн, потока тепла, диффузии, статистического или динамического электричества, и т. д., за ис-

static or dynamic electricity, etc, except that we here deal with partial differential equetions.

ключеннем того что мы здесь будем рассматривать дифференцнальные уравнения в частных производных.

Equations involving more than one independent variable and the partial derivatives of the dependent variables with respect to the independent variables are called partial differential equations.

Уравнения, содержащче более чем одну независнмую переменную н частные пронзводные завнснмых переменных относительно независимых переменных называются днфференцнальнымн уравненнями в частных производных.

It is often impossible, however, to perform the actual elimination, and hence this tranformations is of theoretical rather than practical interest.

Часто невозможно, тем не менее, выполнить действительные нсключення, н следовательно это преобразование имеет теоретнческий скорее чем практнческнй нтерес.

To illustrate the use of equation 54.4 we apply it to the approximate solution of the differential equation.

Для того чтобы иллюстрировать применение уравнения 54.4 мы будем прнменять его для приближенного решения дифференциального уравнения.

There are various numerical methods for this purpose.

Имеются разные чнсленные методы для этой целн.

It is necessary to find values between which the function f(x) is zero.

Необходимо найти значения, между которыми фуакция f(x) есть нуль.

Suppose that both equations actually contain all the possible partial derivatives of second order.

Допустим, что оба уравнення действительно содержат все возможные частные производные второго порядка.

In problems of this type numerical methods become a necessaity due to absence of other methods for getting the requisite information out of the differential equations.

В задачах этого типа численные методы становятся необходимостью обусловленной отсутствием других методов для получения необходимого сведения из дифференциальных уравнений.

This was based on an expensive experiment done by myself and Dr. R. H. Richens, of Cambridge University, in which we worked out a method of translating small sections of selected text in foreign languages. We gave an account of this at a conference in Massachusetts in 1952, after which the International Business Machines Company, in conjunction with Georgetown University, applied our methods to give a popular demonstration which was limited to translating a few sentences form Russian into English. There is no possibility at present of translating a book as a work of art.

Это было основано на дорогом эксперименте проведенном мной н доктором R. H. Richens, от Кэмбриджского Университета, в котором мы разработали метод перевода малых отрывков выбранного текста на иностранные языкн. Мы дали отчет о этом на конференцин в Massachusetts в 1952, после которогс I.B.M. компания в сотрудничестве с Джорджтаунским Университетом прнменили нашн методы чтобы дать наглядную демонстрацию, которая была ограничена переводом нескольких предложений с русского на английский. Не имеется возможности в настоящее время перевода книги как произведения искусства.

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